

What is claimed is:

1. A method for forming an insulating film on a substrate to be processed, comprising the steps of:

5 forming nitrogen radicals and oxygen radicals using a high frequency plasma; and

supplying the nitrogen radicals and the oxygen radicals to a surface of the substrate to form the insulating film thereon.

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2. A method for forming an insulating film on a silicon-containing substrate to be processed, comprising the steps of:

15 forming a gas mixture by mixing a nitrogen gas or a nitrogen compound gas with an oxygen gas or an oxygen compound gas;

exciting the gas mixture using a high frequency plasma to produce nitrogen radicals and oxygen radicals;

20 supplying the nitrogen radicals and the oxygen radicals to a surface of the substrate; and

creating an insulating film containing nitrogen with the nitrogen radicals and the oxygen radicals on the surface of the substrate.

25 3. The method of claim 2, wherein the substrate is a silicon substrate and the insulating film is an oxynitride

film.

4. The method of claim 2, wherein the gas mixture forming
step includes the process in which the mixture ratio between
5 the oxygen gas or the oxygen compound gas and the nitrogen
gas or the nitrogen compound gas varies with time.

5. The method of claim 2, wherein the nitrogen radicals
and the oxygen radicals are supplied onto the substrate by
10 being carried by a stream of gas formed to flow along the
surface of the substrate.

6. The method of claim 5, wherein the stream of gas flows
from one side of the substrate to another side facing
15 diametrically against said one side.

7. The method of claim 2, wherein the high frequency
plasma is produced by exciting the nitrogen gas and the
oxygen gas at a frequency of 400 kHz - 500 kHz.

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8. A method for manufacturing a semiconductor device,
comprising the steps of:

forming nitrogen radicals and oxygen radicals using a
high frequency plasma;

25 supplying the nitrogen radicals and the oxygen
radicals to a surface of a semiconductor substrate and

processing the surface of the substrate; and

forming an active device on the substrate having the processed surface.

5 9. A method for manufacturing a semiconductor device, comprising the steps of:

forming a gas mixture by mixing a nitrogen gas or a nitrogen compound gas with an oxygen gas or an oxygen compound gas;

10 exciting the gas mixture using a high frequency plasma to produce nitrogen radicals and oxygen radicals;

supplying the nitrogen radicals and the oxygen radicals to a surface of a silicon-containing substrate to be processed;

15 creating an insulating film containing nitrogen on the surface of the substrate with the nitrogen radicals and the oxygen radicals; and

forming a semiconductor device on the substrate which has the insulating film.

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10. The method of claim 9, wherein the substrate is a silicon substrate and the insulating film is an oxynitride film.

25 11. The method of claim 9, wherein the gas mixture forming step includes the process in which the mixture ratio between

the oxygen gas or the oxygen compound gas and the nitrogen gas or the nitrogen compound gas varies with time.

12. The method of claim 9, wherein the nitrogen radicals
5 and the oxygen radicals are carried by a stream of gas along the surface of the substrate.

13. The method of claim 12, wherein the stream of gas
10 flows from one side of the substrate to another side facing diametrically against said one side.

14. The method of claim 9, wherein the high frequency
15 plasma is produced by exciting the nitrogen gas and the oxygen gas at a frequency of 400 kHz - 500 kHz.

15. The method of claim 9, further comprising the step of
forming a gate insulating film of a high-k dielectric material on the insulating film.

20 16. An apparatus for processing a substrate to be processed, comprising:

a radical forming unit for forming nitrogen radicals and oxygen radicals using a high frequency plasma; and

a processing vessel for holding the substrate,
25 wherein the radical forming unit includes a supply port for feeding the nitrogen radicals and the oxygen

radicals produced in the radical forming unit to the processing vessel, and the nitrogen radicals and the oxygen radicals are supplied to a surface of the substrate held in the processing vessel to form an insulating film thereon.

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17. The apparatus of claim 16, further comprising a gas inlet port attached to the radical forming unit for feeding a gas mixture into the radical forming unit, wherein the gas inlet port controls the gas mixture to have a desired
10 mixture ratio between a first source material gas containing nitrogen and a second source material gas containing oxygen, and wherein the ratio between the nitrogen radicals and the oxygen radicals formed in the radical forming unit is controlled through an adjustment of the mixture ratio
15 between the first source material gas and the second source material gas.

18. The apparatus of claim 16, wherein the radical forming unit is placed at a side of the processing vessel and
20 generates a stream of gas flowing along the surface of the substrate, and wherein the nitrogen radicals and the oxygen radicals are supplied onto the surface of the substrate by being carried along the surface of the substrate by the stream of gas.

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19. The apparatus of claim 16 or 18, wherein the

processing vessel has a gas exhaust port for evacuating the nitrogen radicals and the oxygen radicals at an opposite side of the supply port of the radical forming unit.

- 5 20. The apparatus of claim 16, wherein the radical forming unit further includes frequency application means for exciting the gas mixture with a frequency of 400 kHz - 500 kHz.